

UNDERWATER DEVICE WITH TRANSMITTER

Field of the Invention

[0001] The present invention relates generally to underwater devices.

Background

[0002] There are circumstances when it is desirable to track an underwater object, typically a man-made object. In some cases, it will be desirable to track the object for an extended period of time and over great distances. In some situations, it is advantageous to implement the tracking in such a way that the tracked object, or an entity controlling it, is unaware that it is being tracked.

Summary

[0003] The illustrative embodiment of the present invention is an apparatus that attaches to a moving, typically man-made, underwater object.

[0004] In the illustrative embodiment, the apparatus includes a housing, which in some embodiments is configured to look like an underwater organism, such as a remora. Within or on the housing is a coupling device by which the housing couples to the underwater object. In some embodiments, the coupling device is a magnet. The magnet is advantageously an electromagnet, so that, with an appropriate control mechanism, the housing can be decoupled from the object.

[0005] The housing also incorporates a transmitter. The transmitter generates and transmits a signal that can be received and processed by appropriate tracking electronics, thereby enabling the moving underwater object (to which the apparatus is attached) to be tracked. The transmitted signal is advantageously an acoustic signal.

[0006] The housing also includes an energy storage device (*e.g.*, capacitor, battery, etc.). The energy storage device is used to power the transmitter and, as required, the coupling device. The housing also incorporates a generator, which generates that is stored in the energy storage device. In some embodiments, energy generated by the generator can be directly delivered to the transmitter and/or coupling device as well as being directed to the energy storage device.

[0007] In the illustrative embodiment, a portion of the housing is physically adapted to move (*e.g.*, back and forth in the manner of the posterior section of a swimming

fish, etc.) when the apparatus is moved through the water (by the underwater object to which it is attached). The movement of the housing drives the generator. More particularly, in some embodiments, the generator comprises a piezoelectric polymer film that is coupled to the movable portion of the housing. As the movable portion moves, the strain energy in the housing is transformed to electrical energy by the piezoelectric polymer film.

[0008] In a further aspect of the invention, a method is disclosed. In some embodiments, the method comprises the operations of:

- reversibly coupling a housing to an object that is submerged in water;
- generating energy by moving said housing through said water;
- storing the generated energy in an energy storage device; and
- delivering the stored energy to a transmitter.

[0009] These and other features of the illustrative embodiment of the present invention are described in detail in the following Detailed Description and depicted in the appended Drawings.

Brief Description of the Drawings

[0010] **FIG. 1** depicts an apparatus in accordance with the illustrative embodiment of the present invention.

[0011] **FIG. 2** depicts a transmitter for use in conjunction with the apparatus of FIG. 1.

[0012] **FIG. 3** depicts a remora.

[0013] **FIG. 4** depicts a variation of the illustrative embodiment, wherein the housing of the apparatus has a remora-like shape and look.

[0014] **FIG. 5** depicts the apparatus of FIG. 3 coupled to an underwater object.

[0015] **FIG. 6** depicts a flow chart of method in accordance with the illustrative embodiment of the present invention.

Detailed Description

[0016] FIG. 1 depicts apparatus **100** in accordance with the illustrative embodiment of the present invention. In some embodiments, apparatus **100** reversibly attaches to a moving, typically man-made, underwater object.

[0017] In the illustrative embodiment depicted in FIG. 1, apparatus **100** includes housing **102**, coupling device **104**, decoupling device **106**, transmitter **108**, energy storage device **110**, and generator **112**, electrically coupled as shown. Coupling device **104**, decoupling device **106**, transmitter **108**, energy storage device **110**, and generator **112**, are *physically associated* with housing **102**. The term “physically associated,” as used in this specification in this context, means that the element of interest (e.g., coupling device, etc.) is disposed completely or partially within housing **102** or is disposed on the exterior of housing **102**.

[0018] Housing **102** is formed of a material that is suitably robust (e.g., will not crack, corrode, dissolve, etc.) for the environment in which it will be used (e.g., fresh water, sea water). For example, in some embodiments, housing **102** is formed from a polymer (e.g., plastic, etc.) In some embodiments, housing **102** is formed from a flexible or pliable material, such as rubber, etc. Those skilled in the art will be able to select a variety of others materials for use as housing **102**.

[0019] Housing **102** can have virtually any shape, although a specific application will often suggest a particular form factor. For any of a variety of reasons, it will often be desirable to provide housing **102** with a shape or configuration that is a replica of, or at least suggestive of an underwater organism. An example of a housing configured as an underwater organism — a remora — is described later in this specification.

[0020] Coupling device **104** couples housing **102** to an underwater object. In some embodiments in which the underwater object is magnetic, coupling device **104** is a magnet, such as a permanent magnet or an electromagnet. Other implementations of coupling device **104** (e.g., hooks, suction cups, netting, etc.) can suitably used as a function of the specifics (e.g., shape, material, etc.) of the underwater object of interest.

[0021] In certain circumstances, it might be desirable to be able to decouple apparatus **100** from the underwater object to which it is coupled. For example, in some applications, it might be necessary or otherwise advantageous to decouple apparatus **100** from an underwater object if that object surfaces, stops moving, etc. Consequently, in some embodiments, apparatus **100** includes decoupling device **106**.

[0022] The specifics of decoupling device **106** depend, to some extent, on the structure of coupling device **104**. For example, in embodiments in which coupling

device **104** is an electromagnet, decoupling device **106** can be, for example, a switch that interrupts power to the electromagnet. Assume, for example, that the event that triggers decoupling is the depth of apparatus **100** (e.g., decouple when apparatus **100** is at or above a depth of 5 meters, etc.). For such a scenario, in some embodiments, a pressure switch is used as decoupling device **106**. In particular, the pressure switch can be electrically connected between the energy supply for the electromagnet and the electromagnet. Below a target depth, the switch is closed so that electricity flows to the electromagnet. But at or above the target depth, the pressure switch opens so that the electromagnet is no longer powered. Apparatus **100** then decouples from the underwater object. In view of the present teachings, those skilled in the art will be able to appropriately select and use a variety of other types of devices as decoupling device **106**.

[0023] Transmitter **108** is used to transmit a signal, either continuously or intermittently. Transmitter **108** is powered by energy storage device **110**, or directly via generator **112**.

[0024] In most embodiments, the transmitted signal is acoustic. The transmission of an acoustic signal is generally preferably due to the limitations associated with the transmission of electronic or optical signals (e.g., transmitter-size requirements for electronic signals and limited propagation distance for optical signals, etc.).

[0025] FIG. 2 depicts an embodiment of transmitter **108** for use in applications in which the transmitted signal is an acoustic signal. In the embodiment depicted in FIG. 2, transmitter **108** includes signal-generating circuit **214** and transducer **216**. In some embodiments, signal-generating circuit **214** is an RC circuit. Transducer **216** changes the form of the signal generated by signal-generating circuit **214**. For example, in some embodiments in which the transmitted signal is an acoustic signal, the transducer **216** is a speaker.

[0026] Generator **112** enables apparatus **100** to operate for an extended period of time by either directly or indirectly powering coupling device **104** and/or transmitter **108**. Generator **112** is advantageously powered by mechanical energy from the surrounding water.

[0027] More particularly, in operation, apparatus **100** is coupled to an underwater object. When the underwater object moves, apparatus **100** moves along with it, creating a flow of water past apparatus **100**. The energy from the flowing water is harnessed by generator **112**.

[0028] A variety of mechanisms or arrangements can serve as generator **112**. In some embodiments, generator **112** comprises a water wheel and an electrical generator. Housing **102** has an opening that is positioned to enable water to "flow" past the water wheel as apparatus **100** is moved through the water. The "flow" of water turns the water wheel which, in turn, cranks the electrical generator.

[0029] In some other embodiments, a hydropiezoelectric generator is used to generate electricity. This technology is under development by Ocean Power Technologies Inc. of Pennington, New Jersey. (See, e.g., "Energy Harvesting Eel Program," www.darpa.mil/dso/trans/energy/pa_opt.html) As employed in conjunction with the illustrative embodiment, the hydropiezoelectric generator is implemented using a piezoelectric polymer film or sheet and a variation of housing **102**.

[0030] In one such embodiment, a portion of housing **102** is physically adapted to move independently of the rest of the housing as apparatus **100** is dragged through water. That is, the housing is hinged, jointed, or otherwise flexible to enable independent movement of a portion thereof. For example, in some embodiments, the movable portion of housing **102** is appropriately configured, based on hydrodynamics, etc., to move back and forth as apparatus **100** is dragged through the water (e.g., similar to the movement of the posterior portion of a fish as it swims through water).

[0031] Coupled to the movable portion of housing **102** are one or more piezoelectric polymer films or sheets. In some embodiments, the piezoelectric polymer comprises polyvinylidene fluoride. Since they are coupled, the piezoelectric polymer film moves as the movable portion of housing **102** moves. Electrodes are attached to film. The movement (*i.e.*, stretching and releasing) of the film generates high voltage, low-frequency electricity. The electricity passes to the electrodes and is then conditioned, as appropriate. The energy can be stored in energy storage device **110** and/or used to directly power one or both of coupling device **104** and transmitter **108**.

[0032] As previously described, in some embodiments, housing **102** advantageously has a shape or configuration that is a replica of, or at least suggestive of an underwater organism. In some embodiments of apparatus **100**, housing **102** is configured like a remora. Remora fish **318** is depicted in FIG. 3, and housing **102** configured to look like a remora is depicted in FIG. 4.

[0033] A remora is any of several species of warm-water fishes of the family Echineidae, which are characterized by an oval sucking disk **320** on the top of the head. This disk, which is a modification of the dorsal fin, enables the remora to attach itself to a shark, swordfish, marlin, sea turtle, and even boats. The various species of remora range in size from about 18 centimeters to 90 centimeters in length.

[0034] In the embodiment of apparatus **100** that is depicted in FIG. 4, remora-shaped housing **102** includes coupling device **104**, decoupling device **106**, transmitter **108**, energy storage device **110**, and generator **112**. In the pictured embodiment, coupling device **104** is implemented as an electromagnet, decoupling device **106** is implemented as a pressure switch, transmitter **108** includes a signal-generating circuit **214** and a transducer **216**, energy storage device **110** is a bank of capacitors, and generator **112** is implemented as a hydropiezoelectric generator.

[0035] Coupling device **104** is disposed at anterior portion **422** of housing **102**. While sucking disk **320** of a remora fish is located on top of the head, coupling device **104** can be located either at dorsal region **424** or ventral region **426** (as shown). In the illustrative embodiment, coupling device **104** (the electromagnet) is located completely within housing **102**. In some other embodiments (not depicted), at least a portion of coupling device **104** is located outside of housing **102**.

[0036] The hydropiezoelectric generator is disposed at posterior portion **428** of housing **102**. Tail fin **430** is configured, in known fashion in accordance with hydrodynamics, so that as apparatus **100** is moved through water, tail fin **430** moves back and forth.

[0037] Piezoelectric polymer film **432** is coupled to the movable portion of housing **102** (e.g., tail fin **430**, etc.) so that the film moves as the movable portion of housing **102** moves. As previously described, the piezoelectric polymer film produces a small current when flexed. This is used to charge the capacitors (energy storage device **110**) or directly drive the electromagnet (coupling device **104**) and/or transmitter **108**, or both.

[0038] In use, apparatus **100** is deployed in any convenient manner (e.g., dropped from an aircraft, launched by an underwater vessel, etc.) in the path of the underwater object of interest. Coupling device **104** couples housing **102** to the object of interest. Assuming that the object of interest is moving, apparatus **100** will turn into the water flow. That is, apparatus **100** will orient itself such that the

anterior portion of housing **102** will be leading (assuming that coupling device **104** is disposed proximal to the anterior portion of housing **102**). FIG. 5 depicts apparatus **100** coupled, via coupling device **104**, to moving, underwater object of interest **534**.

[0039] If the object of interest rises above a certain depth, the pressure switch (*i.e.*, decoupling device **106**) will open thereby de-energizing the electromagnet. Consequently, apparatus **100** will decouple from the object of interest. In some other embodiments, it is desirable for apparatus **100** to decouple when the object of interest stops moving. In some of these embodiments, decoupling device **106** comprises an accelerometer (*e.g.*, a MEMS accelerometer, *etc.*) and a switch. If the object of interest stops moving, the accelerometer causes the switch to open, thereby de-energizing the electromagnet.

[0040] FIG. 6 depicts a flow diagram of method **600** in accordance with the illustrative embodiment of the present invention.

[0041] Operation **602** of method **600** requires reversibly coupling an apparatus to an object that is submerged in water, wherein the apparatus is capable of transmitting a signal. As previously described, this can be performed using an electromagnet or other devices.

[0042] Operation **604** recites generating energy by moving the apparatus through the water. This can be done in a variety of ways, such as by using a water wheel or a hydropiezoelectric generator.

[0043] In operation **606**, at least a portion of the energy that is generated is stored in an energy storage device. As previously described, stored energy can be delivered to a bank of capacitors, rechargeable batteries, and the like.

[0044] According to operation **608**, the stored energy is delivered to a transmitter, and in operation **610**, the transmitter sends a signal.

[0045] It is to be understood that the above-described embodiments are merely illustrative of the present invention and that many variations of the above-described embodiments can be devised by those skilled in the art without departing from the scope of the invention. For example, in some variations of the illustrative embodiment, the rotary-acting valve functions as a single-stage valve for any of a variety of services. And in some other variations of the illustrative embodiment, the rotary-acting valve serves as the first stage of a valve having more than two stages.

It is therefore intended that such variations be included within the scope of the following claims and their equivalents.